POTATO GLYCOALKALOIDS: INCREASES AND VARIATIONS OF RATIOS IN AGED SLICES OVER PROLONGED STORAGE[1]

T. J. Fitzpatrick, S. F. Herb, S. F. Osman, and J. A. McDermott
Eastern Regional Research Center[2]
Philadelphia, Pennsylvania 19118

Abstract

Four commercial cultivars of potatoes were maintained under normal storage conditions at 44 F for 34 weeks. Except for a final 10 week interval tubers were withdrawn at 6 week intervals. After slicing, a portion of the slices was immediately analyzed for total glycoalkaloid content. The remaining slices were aged for four days in the dark at room temperature, then similarly analyzed.

The total glycoalkaloid content of the aged slices increased dramatically on aging. This increase on aging of slices reached a maximum early in storage then decreased gradually over the storage period. In determining the individual glycoalkaloids, α-solanine and α-chaconine both increased in these slices, but the greatest increase was in the former. Appearing solely in the aged slices of the Kennebec variety, α-and β-solamarine appeared early in the storage period and gradually decreased over the storage period. Analyses of the unaged slices indicated that the glycoalkaloid content and composition of the potato tubers was little affected by storage. Aging of potato sprouts did not change their glycoalkaloid content.

Resumen

Se mantuvieron cuatro cultivares comerciales de papa bajo condiciones normales de almacenamiento a 44°F por 34 semanas. Con excepción del intervalo final de 10 semanas, los tubérculos se sacaron a intervalos de 6 semanas. Después de obtener discos de los tubérculos, una porción de los discos fue inmediatamente analizada para determinar el contenido de glicoalcaloides totales. El resto de los discos se envejecieron en la oscuridad, a temperatura de cuarto por cuatro días, luego se analizaron en forma similar.

El contenido de glicoalcaloides totales aumentó dramáticamente en los discos envejecidos. Este aumento con la edad de los discos, alcanzó un máximo al inicio del almacenamiento, luego disminuyó gradualmente conforme avanzó el período de almacenamiento. En la determinación de

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los glicoalcaloides individuales, α-solanina y α-chaconina aumentaron en los discos, pero el aumento más grande fue con el primero. Apareciendo solos en los discos envejecidos de la variedad Kennebec, α-y β-solamarina apareció al inicio del período de almacenamiento y gradualmente disminuyó durante el período de almacenamiento. Los análisis de los discos sin almacenamiento indicaron que el contenido de glicoalcaloides y la composición de los mismos en los tubéculos de papa fueron muy poco afectados por el almacenamiento. El envejecimiento de los brotes de papa no cambió su contenido de glicoalcaloides.

Introduction

Glycoalkaloides, which are steroidal nitrogenous compounds, are found in all solanaceous plants. They may function as factors in insect resistance (8), although evidence for this is not conclusive. It has been postulated that certain instances of illness or death attributed to the consumption of potatoes have been due to high levels of glycoalkaloids. Although the major potato glycoalkaloids are much less toxic when administered orally than when administered intraperitoneally (6), there has been much concern about the presence of high glycoalkaloid levels (above 20 mg/100 g fresh weight) in potato tubers.

Many factors affect the levels of glycoalkaloids in potatoes. These include exposure to light, soil types, fertilizations practices, climate, altitude, and tuber size, maturity, and damage (11). Varietal differences and genetics also play an important role in total glycoalkaloid (TGA) levels (7).

Long storage of certain varieties of tubers at low temperatures after harvest has been shown by some researchers to have little effect on the TGA level of these tubers (12). Others have reported that stored tubers contain significantly more solanine than fresh tubers (1). In an attempt to resolve this point we have measured the glycoalkaloid content of four commercial cultivars over extended storage periods. Following up reports that stressed tubers will accumulate glycoalkaloids (5) and that in some cases new glycoalkaloids are actually formed (10), we studied these phenomena. In addition to TGA analysis, we studied the changes in glycoalkaloid composition during storage. These have not been previously reported.

Materials and Methods

Four varieties of potatoes from Maine were used: Kennebec, Katahdin, Houma, and Wauseon. These were stored in 50 lb paper bags in an unlighted cold room at 44 F and 85% relative humidity. Representative samples of 6-8 tubers were removed at 6-week intervals over the storage

period from 0 time (about one month after harvest) to 24 weeks, then at a 10-week interval for a total of 34 weeks. At this time advanced sprouting had taken place and these sprouts also were collected for analysis.

Each time a sample of tubers was taken for analysis, the following procedure was carried out: the washed but unpeeled tubers were cut in half from stem to bud end. Slices were then cut from each half. Slices from one half were minced thoroughly and 20 g aliquots (two replications) were taken for analysis. These were extracted (2) by grinding in a Waring Blendor with a mixture of methanol and chloroform (2:1, v/v). This bisolvent system was separated by adding a saturated sodium sulfate solution, the glycoalkaloids partitioning into the methanol-water layer. The glycoalkaloids from aliquots of the methanol-water solution were hydrolyzed by heating for two hours on a steam bath in 2N H_2SO_4. With the sugars cleaved off, the hydrolysates were made basic with 4N NaOH, and the aglycones were extracted with benzene. After evaporation of the benzene, the TGA were dissolved in methanol and titrated according to the method for TGA analysis previously reported (2).

Slices (20 g) from the opposing half of the tuber were placed in covered petri dishes and aged at room temperature in the dark for ca. 96 hours. When these aged slices were removed from storage they were analyzed in the above manner. The TGA for both is reported as mg/100 g fresh weight (Table 1).

TABLE 1—*Total Glycoalkaloid content*[1] *of unaged and aged*[2] *tuber slices from four varieties of stored potatoes.*[3]

	0 Time	6 Week	12 Week	18 Week	24 Week	34 Week
Unaged Wauseon	3.16	5.27	4.84	3.01	3.61	5.53
Aged Wauseon	77.88	126.43	145.85	108.24	92.45	64.38
Unaged Katahdin	5.61	11.09	7.47	11.48	9.35	9.02
Aged Katahdin	106.26	117.66	130.21	143.73	137.04	102.31
Unaged Houma	3.83	6.39	4.93	3.02	3.65	7.30
Aged Houma	58.97	51.89	34.67	84.20	95.46	61.88
Unaged Kennebec	9.38	6.84	10.42	7.24	6.39	11.24
Aged Kennebec	154.56	—	150.50	158.88	163.09	119.52

[1] All values expressed as mg/100 g fresh weight.
[2] Four days in dark room at ambient temperature.
[3] Controlled storage, 44 F and 85% relative humidity.

At the end of the 34-week storage period, all of the tubers had developed sprouts several inches long. These sprouts were detached from the tubers and analyzed separately. The TGA content of sprouts did not change with aging. The TGA of sprouts is listed in Table 3.

Appropriate aliquots of the methyl alcohol extracts were taken for gas chromatographic analysis. The size of the aliquot of the extract was adjusted according to the amount of glycoalkaloids present. Typically, 25 ml were used for the unaged slices and 10 ml were taken for the aged samples. The permethlyated derivatives of the glycoalkaloids were prepared and separated by the gas chromatographic procedure developed at this laboratory and previously reported (4).

The relative amounts of each glycoalkaloid (expressed as percent) over the storage period are reported in Table 2.

Results and Discussion

The metabolic behavior of potato tuber slices during aging is commonly considered a rejuvenation phenomenon involving the initiation of protein

TABLE 2—*Percentages of the major glycoalkaloids in unaged vs. aged tuber slices from potatoes stored at 44 F.*

	Wauseon				Houma			
	Unaged		Aged[1]		Unaged		Aged[1]	
Storage Weeks	α-chac[2]	α-sol[3]	α-chac[2]	α-sol[3]	α-chac[2]	α-sol[3]	α-chac[2]	α-sol[3]
	%	%	%	%	%	%	%	%
0	74.6	25.4	49.6	50.4	69.0	31.0	50.0	50.0
6	68.7	31.3	44.4	55.6	67.2	32.8	48.3	51.7
12	66.2	33.8	40.6	59.4	68.1	31.9	43.2	56.8
18	86.0	14.0	44.8	55.2	74.5	25.5	46.1	53.9
24	80.1	19.9	44.0	56.0	71.8	28.2	42.5	57.5
34	73.3	26.7	43.4	56.6	70.1	29.3	40.1	59.9

	Katahdin				Kennebec					
	Unaged		Aged[1]		Unaged		Aged[1]			
Storage Weeks	α-chac[2]	α-sol[3]	α-chac[2]	α-sol	α-chac[2]	α-sol[3]	α-chac[2]	α-sol[3]	β-sola[4]	α-sola[4]
	%	%	%	%	%	%	%	%	%	%
0	64.1	35.9	42.7	57.3	58.9	41.1	24.9	37.1	11.5	26.5
6	58.4	41.6	37.2	62.8	54.9	45.1	26.8	33.3	12.4	27.5
12	60.8	39.6	38.5	61.5	52.3	47.7	24.3	43.4	8.3	24.0
18	65.2	34.8	35.3	64.7	59.8	40.2	28.2	44.6	6.8	20.5
24	67.0	33.0	36.5	63.5	63.9	36.1	26.6	54.0	4.6	14.8
34	65.0	35.0	38.0	62.0	57.7	42.3	23.8	56.0	5.6	14.6

[1] Four days in dark room at ambient temperature.
[2] α - Chaconine.
[3] αSolanine.
[4] Solamarines (found only in Aged Kennebec slices).

TABLE 3—*Total and specific glycoalkaloids in potato sprouts*[1]

Variety	Total Glycoalkaloids	α-Chaconine	α-Solanine
Unaged Houma	327.76	56.1	43.9
Aged[2] Houma	325.30	–	–
Unaged Kennebec	296.15	51.5	48.5
Aged Kennebec	297.39	51.7	48.3
Unaged Wauseon	352.25	56.8	43.2
Unaged Katahdin	320.22	57.7	42.3

[1]From tubers stored for 34 weeks at 44 F and 85% rel. humidity.
[2] Four days in dark room at ambient temperature.

synthesis (3). There was a great increase in potato glycoalkaloids when slices were aged (Table 1). Why this accumulation occurs is not completely understood. It is known that under these conditions there is a marked increase in the rate of respiration, synthesis of protein, RNA, and free sterols and an increase in the activity of several enzymes (3). It has been reported that many of the alkaloids are biosynthesized from cholesterol or a biogenic equivalent (9). It would follow, therefore, that an accompanying increase in glycoalkaloids would not be unexpected.

In unaged tuber slices in which the TGA was relatively low, there was little apparent TGA change during storage, as most of the differences were within the limitations of experimental error. Changes in TGA during storage of the tubers, therefore, appear to be minor. With the 20-30 fold TGA increases in the aged tuber slices, a clearer picture emerges; in all cases, the TGA increased to a maximum and then decreased gradually for the duration of the storage period. The length of time in storage to achieve this maximum varied from 12 weeks to 24 weeks depending on the variety. As would be expected, there was a very high glycoalkaloid content in the sprouts which did not increase or change in composition when the sprouts were sliced and incubated (See Table 3).

In the unaged slices, the ratio of α-solanine to α-chaconine changed very little over the 34-week storage period (Table 2). In the aged slices, however, even though both α-solanine and α-chaconine increased (Table 1), the former increased to a greater extent than the latter (Table 2).

The Kennebec variety differed from the other three in that aging of slices also caused the formation of two additional glycoalkaloids, α- and β-solamarine. While the aged Kennebec slices also exhibited the relative increase in α-solanine as compared with α-chaconine, there was a general

decrease in both solamarines throughout the storage period even though the α-solamarine (the greater of these two components) has the same carbohydrate structure as α-solanine and the β-solamarine has the same carbohydrate structure as α-chaconine.

The results of this study indicate that no significant buildup of glycoalkaloids would take place during prolonged storage of commercial varieties of potatoes. However, should potato tubers be prepeeled, sliced, or otherwise disrupted and then held at room temperature for an extended period of time without blanching or cooking, there is a possibility that glycoalkaloids - especially solanine - might accumulate to an undesirable level.

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Literature Cited

1. Cronk, T. C., G. D. Kuhn, and F. W. McArdle. 1974. The influence of stage of maturity, level of nitrogen fertilization and storage on the concentration of solanine in tubers of three potato cultivars. Bull Environ Contam Toxicol 11:163-168.
2. Fitzpatrick, T. J., and S. F. Osman. 1974. A comprehensive method for the determination of total potato glycoalkaloids. Am Potato J 51:318-323.
3. Hartman, M. A. and P. Benveniste. 1974. Effect of aging on sterol metabolism in potato tuber slices. Phytochemistry 13:2667-2672.
4. Herb, S. F., T. J. Fitzpatrick, and S. F. Osman. 1975. Separation of potato glycoalkaloids by gas chromatography. Agric Food Chem 23:520-523.
5 Locci, R., and J. Kuc. 1967. Steroid alkaloids as compounds produced by potato tubers under stress. Phytopathology 57:1272-1273.
6. Nishie, K., M. R. Gumbann, and A. C. Keyl. 1971. Pharmacology of solanine. Toxicol Appl Pharmacol 19:81-82.
7. Sanford, L. L. and S. L. Sinden. 1972. Inheritance of potato glycoalkaloids. Am Potato J 49:209-217.
8. Schreiber, K. 1957. Naturally occurring plant resistance factors against the Colorado Potato Beetle (*Leptinotarsa decemlineata*) and their possible mode of action. Zuchter, 27:289-299.
9. Schreiber, K. 1974. Synthesis and biogenesis of steroidal alkaloids. Biochem Soc Trans 2:1-25.
10. Shih, M. and J. Kuc. 1974. α- and β-Solamarine in Kennebec *Solanum tuberosum* leaves and aged tuber slices. Phytochemistry. 13:997-1000.
11. Sinden, S. L. and R. E. Webb. 1974. Effect of environment on glycoalkaloid content of six potato varieties at 39 locations. USDA ARS Tech Bull 1472 U.S. Dep Agric.
12. Wolf, M. J. and B. M. Duggar. 1946. Estimation and physiological role of solanine in the potato. J Agric Res 73:1-32.